PREDICTION OF TYRE FRICTION

MUHAMAD MUHAIMIN BIN SHAARI

A Report in Partial Fulfillment of the Requirements for the Award of the Degree Of
Bachelor of Mechanical Engineering

FACULTY MECHANICAL ENGINEERING
UNIVERSITI MALAYSIA PAHANG

MAY 2009

ACKNOWLEDGEMENTS

First Of All I Would Like To Express My Fully Gratitude And Praise 'Alhamdulilah' To Allah The Almighty For Completion Of This Research. To My Supervisor, Dr. Kumaran A/L Kadirgama, Thanks For All Your Guidance, Support And Time For Me. Without Her Continued Support And Interest, This Thesis Would Not Have Been The Same As Presented Here.

To My Beloved Family, Thank You For Your Support And Understanding. I Acknowledge Without Endless Love And Relentless Support From My Family, I Would Not Have Been Here. Father, Mother, Sister And Brothers, You All Have Given Me The Inspirations And Encouragement Until These Days.

Last But Not Least, To My Course Mates, Thanks For The Supports And Helps On My Research. I Could Never Repay And To All Whose I Not Mention Here, I Appreciate Your Helps And Supports To Me.

ABSTRACT

Automotive industry was moving ahead to be an important industry in Malaysia and in the world. Tire is one of the main parts in the car which is always costly. In recent years, much progress has been made in the physical understanding and modelling of the friction behaviour of elastomers at rough and fine surfaces. The friction between the tires of the automobile and the road determine your maximum acceleration, and more importantly the minimum stopping distance. So the nature of that friction could actually be a matter of life and death. The main objective of the project is to determine the friction coefficient of the tyre by using the Algor software. In the beginning of the project, the information about friction, tyre, and the suitable software are gather. Then, the tyre model and the surfaces that represent the road surface condition are draw by using the Solidwork software, and then the model is transferred to the Algor software to run the simulation. From the simulation, the result show that the friction coefficient is about 0.37 to 0.61.from the case study result, this result is approximate to the real value of the coefficient of static friction.

ABSTRAK

Industry automotif telah berkembang maju dan menjadi industri yang penting di Malaysia dan seluruh dunia. Tayar merupakan benda asas yang penting pada kenderaan. Pada masa sekarang, banyak kajian telah dibuat untuk mereka dan memahami tentang sifat dan keadaan geseran antara elastromer dengan permukaan kasar serta licin. Daya geseran antara tayar dan permukaan jalanraya manentukan daya pecutan maksimum, dan yang penting sekali ialah jarak berhenti minimum bagi sesebuah kenderaan. Oleh itu, sifat semulajadi geseran adalah berkait rapat antara hidup dan mati. Objektif utama projek ini adalah untuk menentukan pemalar bagi daya geseran tayar menggunakan perisian Algor. Bermula dengan mencari maklumat tentang geseran, tayar sehingga kepada perisian yang sesuai digunakan. Selepas itu, rekabentuk tayar dan permuka yang mewakili keadaan permukaan jalan di buat menggunakan perisian Solidwork, kemudian dipindah ke perisian Algor untuk menjalankan simulasi. Daripada simulasi tersebut, keputusan yang diperolehi bagi pemalar geseran adalah 0.37 sehingga 0.61. daripada hasil tersebut, didapati keputusan tersebut menyamai pemalar geseran yang sebenar yang diuji di makmal.

TABLE OF CONTENTS

		Page
TITLE PAGE		i
SUPERVISOR DECLARATION		ii
STUDENT DECLARATION		iii
DEDICATION		iv
ACKNOWLEGDEMENTS		v
ABSTRACT		vi
ABSTRAK		vii
TABLE OF CONTENTS		vii
LIST OF TABLES		x
LIST OF FIGURE		xi
CHAPTER 1	**INTRODUCTION**	
1.1	Introduction	1
1.2	Project Background	1
1.3	Problem Statement	2
1.4	Project Objective	2
1.5	Project Scope	2
CHAPTER 2	**LITERATURE REVIEW**	
2.1	Intorduction	3
2.2.	Fundamental Of Tyre	3
2.3	Type Of Tyre	
	2.3.1 Summer Tyre	4
	2.3.2 Winter Tyre	4
	2.3.3 All Season Tyre	5
	2.3.4 Slick Tyre	5
2.4	Friction	6
	2.4.1 Information	8

	2.4.2 Law of Dry Friction	8
2.5	FINITE ELEMENT ANALYSIS	11
2.6	Other Research	12
CHAPTER 3	**METHODOLOGY**	
3.1	Introduction	14
3.2	Find the Information	16
3.3	Design A Tyre Model and Plate Model and Simulation	16
CHAPTER 4	**RESULTS AND DISCUSSION**	
4.1	Introduction	22
4.2	Calculation of X-Direction Force On Tire With Given Weight and Acceleration	22
4.3	Analysis of Tyre Friction Using Different Surface	23
4.4	Summaries of The Tyre Friction Analysis	27
4.5	Results for the Simulation of the Tyre Friction	30
CHAPTER 5	**CONCLUSION AND RECOMMENDATIONS**	
5.1	Conclusions	31
5.2	Recommendation And Future Works	32
REFERENCES		33
APPENDICES		34

LIST OF TABLES

Table No.	Title	Page
2.1	Approximate Value Of Static Coefficient	10
4.1	Force for x-direction	23
4.2	Results of the Tyre Friction for the Surface 1	24
4.3	Results for Tyre Friction for Surface 2	25
4.4	Results for Tyre Friction for Surface 3	26

LIST OF FIGURES

Figure	Title	Page
2.1	Example of Summer Tyre	4
2.2	Tread Of Winter Tyre	5
2.3	All Season Tyre	5
2.4	Slick Tyre	6
2.5	Normal Force	7
2.6	Friction Coefficient	7
2.7	Low of friction	8
2.8	Friction Force versus Applied Load	9
3.1	The framework of methodology	15
3.2	Tyre Model	16
3.3	(a) Plate 1, (b) Plate 2, (c) Plate 3	17
3.4	Meshing	18
3.5	Setting for Unit	18
3.6	Material Specification	19
3.7	Putting Nodal Forces	19
3.8	After Finish Putting Nodal Force	20
3.9	Boundary Condition (Fix)	20
3.10	Result	21
4.1	Coefficient of friction versus acceleration for surface 1	27
4.2	Friction coefficient for surface 2	28
4.3	Friction coefficient for surface 3	29
4.4	Result of the Simulation	30

ABSTRACT

Automotive industry was moving ahead to be an important industry in Malaysia and in the world. Tire is one of the main parts in the car which is always costly. In recent years, much progress has been made in the physical understanding and modelling of the friction behaviour of elastomers at rough and fine surfaces. The friction between the tires of the automobile and the road determine your maximum acceleration, and more importantly the minimum stopping distance. So the nature of that friction could actually be a matter of life and death. The main objective of the project is to determine the friction coefficient of the tyre by using the Algor software. In the beginning of the project, the information about friction, tyre, and the suitable software are gather. Then, the tyre model and the surfaces that represent the road surface condition are draw by using the Solidwork software, and then the model is transferred to the Algor software to run the simulation. From the simulation, the result show that the friction coefficient is about 0.37 to 0.61.from the case study result, this result is approximate to the real value of the coefficient of static friction.

ABSTRAK

Industry automotif telah berkembang maju dan menjadi industri yang penting di Malaysia dan seluruh dunia. Tayar merupakan benda asas yang penting pada kenderaan. Pada masa sekarang, banyak kajian telah dibuat untuk mereka dan memahami tentang sifat dan keadaan geseran antara elastromer dengan permukaan kasar serta licin. Daya geseran antara tayar dan permukaan jalanraya manentukan daya pecutan maksimum, dan yang penting sekali ialah jarak berhenti minimum bagi sesebuah kenderaan. Oleh itu, sifat semulajadi geseran adalah berkait rapat antara hidup dan mati. Objektif utama projek ini adalah untuk menentukan pemalar bagi daya geseran tayar menggunakan perisian Algor. Bermula dengan mencari maklumat tentang geseran, tayar sehingga kepada perisian yang sesuai digunakan. Selepas itu, rekabentuk tayar dan permuka yang mewakili keadaan permukaan jalan di buat menggunakan perisian Solidwork, kemudian dipindah ke perisian Algor untuk menjalankan simulasi. Daripada simulasi tersebut, keputusan yang diperolehi bagi pemalar geseran adalah 0.37 sehingga 0.61. daripada hasil tersebut, didapati keputusan tersebut menyamai pemalar geseran yang sebenar yang diuji di makmal.

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This chapter is discussed about the project background, the problem of the project, the objective of the project and the project scope.

1.2 PROJECT BACKGROUND

Nowadays, tyre has many variant such as high traction, high speed, noiseless, airless, tubeless, wide radial and long lasting.

The friction between the tires of your automobile and the road determine your maximum acceleration and more importantly your minimum stopping distance. So the nature of that friction could actually be a matter of life and death.

Many years of research and practice have led to tread designs for automobile tires which offer good traction in a wide variety of conditions. The tread designs channel water away from the bearing surfaces on wet roads to prevent the tendency to hydroplaning**.**

]

1.3 PROBLEM STATEMENT

There are many way to predict the tyre friction, from calculation, simulation and from experimental. Currently, researchers predict the tyre friction using manual calculation and software. This project mainly concentrates the prediction of tyre friction using Algor software with normal conditions**.**

1.4 PROJECT OBJECTIVE

The objectives of this project are:

1. To predict and study the tyre friction with FEA software
2. To improve knowledge about ALGOR software.

1.5 PROJECT SCOPE

In order to achieve the objectives the following scope of project are performed:

1. Literature review of the tyre, the friction, and the ALGOR software.
2. Gather information of the tyre
3. Design the tyre model and plate
4. Analysis of the current design using ALGOR software.
5. Determined the friction coefficient with certain calculation

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, there will be explanation on the definition of tyre and finite element usage for tyre simulation. This chapter will introduce the fundamental of the tyre and the basic type of tyre. In this chapter also explain about the finite element analysis that been use, that is ALGOR software.

2.2 FUNDAMENTAL OF TYRE

The earliest tyres were bands of iron placed on wooden wheels. It used on carts and wagons. The tyre would be heated in a forge fire, placed over the wheel and quenched causing the metal to contract and fit tightly on the wheel[2].

John Boyd Dunlop invented the first pneumatic tyre in 1887 for his son bicycle, in order to prevent headaches of his son when riding bicycle on rough road[2].

The main material of pneumatic tyres is flexible elastromer material, such as rubber. Fabric and wire are used to reinforce the tyre[2]

The tread is the part of tyre that contact to the road surface. It is design to provide appropriate level of traction.

2.3 TYPE OF TYRE

2.3.1 Summer tyres

This tyre characteristic is excellent driving and braking on dry and wet roads. The tread design in simple block-shape pattern to ensure the tyre's contact remains rigid as possible. This pattern ensures the maximum grip by optimizing friction with road surface [2]. The example of summer tyres is shown in figure 1.

Figure 2.1: Example of Summer Tyre

2.3.2 Winter tyres

This tyres is design for snow and ice covered roads. The tread is fine-block design with grooves that deep and wide as shown in figure 2. This tyre has excellent driving traction and breaking on winter road surface. Winter tyre is design focus on braking and control on icy roads

Figure 2.2: Tread Of Winter Tyre

2.3.3 All season tyres

These tyres are design to bre use all year round. The pattern is more complicated compare to the summer tyre because of the longer block-edge for winter usage shown in figure 3. Compare to the summer tyre, the all season tyres have many sips that improve the braking and driving performance [2].

Figure 2.3: All Season Tyre

2.3.4 Slick tyres

This tyre have more traction than treaded tyres in dry roads but, in wet condition the tyre is less traction than treaded tyre shown in figure 3. This tyre is design for car racing where the competitors can change different tyres based on the weather condition [2].

Figure 2.4: Slick Tyre

2.4 FRICTION

Friction is the force resisting the relative motion of two surfaces in contact. Friction between tyre and road determine the acceleration, and also the brake distance [2].

$F_F = \mu F_\perp$

This is the friction equation, where F_f is the force of friction between two surfaces [3]. The friction between two surfaces can be increased in two ways:

- Increase the coefficient of friction, μ
- Increase the normal force $F_\perp$

$F_\perp$ = The normal force is the force pushing up on the tires shown in figure 3. Caused by the weight of the vehicle and tires, it is in fact equal in size to the weight pressing down on the ground.

Figure 2.5: Normal Force

μ = The coefficient of friction is a number that is determined by the nature of the two surfaces in contact. The 'rougher' the two surfaces are relative to each other, the bigger this number will be and the larger the friction force.

Figure 2.6: Friction Coefficient

2.4.1 Information

Actually, no perfectly frictionless surface exists. When two surfaces are in contact, tangential forces, called friction forces, will always develop if one attempts to move surface with respect to each other. On the other hand, these friction forces are limited in magnitude and will not prevent motion if sufficiently large forces are applied.

There are two types of friction; dry friction called coulomb friction and fluid friction. Fluid friction develops between layers of fluid moving in different velocities. This project is focusing about the dry friction.

2.4.2 Law of dry friction

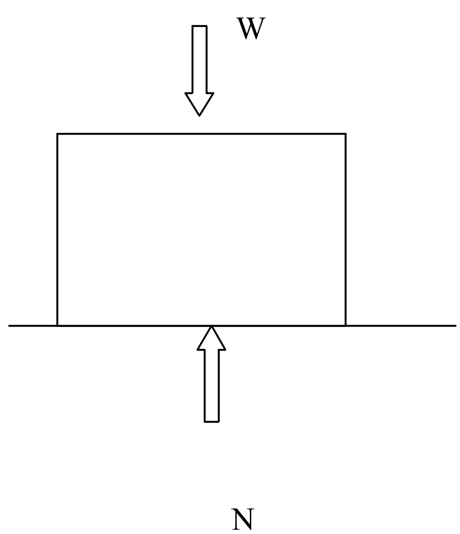

Figure 2.7(a)

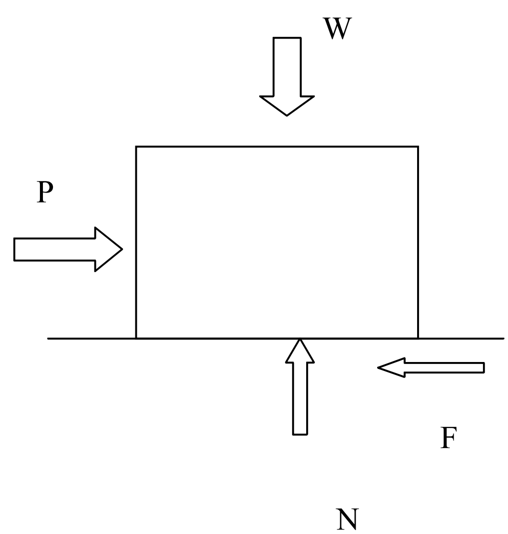

Figure 2.7(b)

The law of the dry friction is explaining by following figure. A block of weight W is placed on a horizontal plane surface in figure 4.8(a). The forces acting on the block are its weight and the reaction of the surface. Since the weight has no horizontal component, the reaction is therefore normal to the surface and represented by N. Now, that a horizontal force, P, is applied to the block in figure 4.8(b). If p is small, the block will not move, some other horizontal force must therefore exist, which balance P. This other force is the static friction force, F, which actually the resultant of the great number forces acting over the entire surface of contact between block and the plane.

If the force P is increase, the friction force F also increase, continuing to oppose P, until its magnitude reaches a certain maximum value F_m in figure 4.9. If P is further increase, the friction force cannot balance it anymore and the block starts sliding. As soon as the block has been set in motion, the magnitude of F drops from F_m to a lower value F_k. This is because there is less interpenetration between irregularities of the surfaces contact when these surface move with respect to each other. From then on, the block keeps sliding with increasing velocity while the friction force, F_k, remain approximately constant.

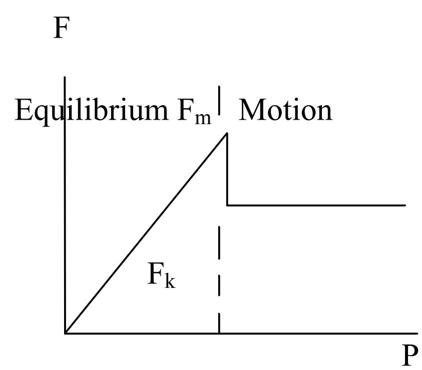

Figure 2.8: Friction Force versus Applied Load

The coefficients of friction do not depend upon the area of the surfaces in contact. However, the friction coefficients depend strongly on the nature of the surface contact. Since they also depend upon the exact condition of the surface, their value is seldom known with accuracy greater than 5 percent. Approximate values of coefficients of static friction for various dry surfaces are shown in table 2.1[11].

Table 2.1: Approximate Value of Coefficient of Static Friction for Dry Surface

Metal on metal	0.15-0.60
Metal on wood	0.20-0.60
Metal on stone	0.30-0.70
Metal on leather	0.30-0.60
Wood on wood	0.25-0.50
Wood on leather	0.25-0.50
Stone on stone	0.40-0.70
Earth on earth	0.20-1.00
Rubber on concrete	0.60-0.90
Rubber on asphalt	0.50-0.80

2.5 FINITE ELEMENT ANALYSIS

The finite element analysis (FEA) is a numerical technique for finding approximate solutions of partial differential equations. Finite Element Analysis is based on the premise that an approximate solution to any complex engineering problem can be reached by subdividing the problem into smaller, more manageable (finite) elements. Using finite elements, complex partial differential equations that describe the behavior of structures can be reduced to a set of linear equations that can easily be solved using the standard techniques of matrix algebra such as Euler's method, Runge-Kutta and else[3].

2.5.1 ALGOR

ALGOR is a general-purpose FEA software that developed by ALGOR Incorporated. Many scientists and engineers used ALGOR software.

ALGOR is typically used to measure bending, the stress and strain, mechanical contact, thermal fluid dynamic and couple and uncouple multiphysics. ALGOR's library of material model consist metal and alloy, plastics, glass, foams, elastromers, concrete and also user-defines material.

ALGOR's element library depends on the geometry and type of analysis performed. Its include 8 and 4 nodes brick, 8 and 4 nodes shell, brick, beam and trusses.

2.6 Other Research

2.6.1 Rubber friction, tread deformation and tyres term traction.

In this research, they research the role of rubber friction in previous tyre traction with special emphasis on the load and velocity dependence of the friction coefficient. In the first part, we present some basic concepts of contact mechanics of slipping previous tyres and analyze the influence of energy dissipation due to tread deformation on the friction force.

Then, apply a recently developed model of hysteresis and adhesion friction of rubber on self-affine road surfaces for estimating the load dependence of the kinetic friction coefficient in the contact area of slipping tyres [4].

2.6.2 Analysis of forced transient response for rotating tyres using REF models.

This paper presents a new approach for tyres dynamic analysis. By using this method, transient response for rotating tyres under various loading situations can be analyzed. The well-known model of ring on elastic foundations (REF) is utilized to model tyre. The general forced solution of undamped inextensible vibration is derived by the use of a modal expansion technique as well as Meirovitch modal analysis method. Closed form transient response for the stationary constant point load case is obtained; for the case of damped vibration, the response of rotating tyre is formulated by using the first-order matrix perturbation theory together with Meirovitch modal analysis method. The effects of damping on the tyre response are investigated. The developed method has been validated by comparison with direct numerical integration results. Combined with a contact or interface model, the proposed methodology can be used to model the tyre dynamic responses under any given road profile [5].

2.6.3 Measurement and analysis of rolling tyre vibrations

This paper presents the measurement and analysis of rolling tyre vibrations due to road impact excitations, such as from cobbled roads, junctions between concrete road surface plates, railroad crossings. Vibrations of the tyre surface due to road impact excitations cause noise radiation in the frequency band typically below 500 Hz. Tyre vibration measurements with a laser Doppler vibrometer are performed on a test set-up based on a tyre to tyre principle which allows highly repetitive and controllable impact excitation tests under various realistic operating conditions. The influence on the measured velocity of random noise, cross sensitivity and alignment errors is discussed. An operational modal analysis technique is applied on sequential vibration measurements to characterize the dynamic behavior of the rolling tyre. Comparison between the operational modal parameters of the rolling tyres and the modal parameters of the non-rolling tyre allows an assessment of the changes in dynamic behavior due to rolling [6].

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the proposed framework for analysis of the tyre friction. The framework of methodology is illustrated in figure 3.1. it consists of the following steps:

i. Find the information
ii. Design tyre model and surface
iii. Run simulation
iv. Collect the data
v. Analysis the data